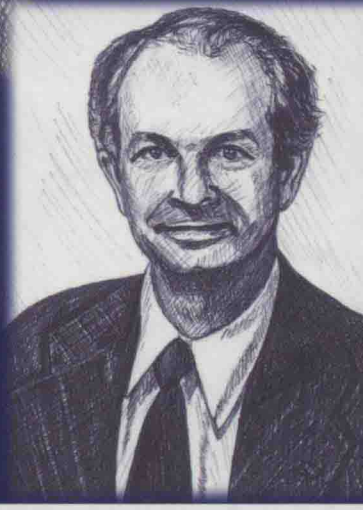
LIVES AND TIMES OF GREAT PIONEERS IN CHEMISTRY

(LAVOISIER to SANGER)



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(LAVOISIER to SANGER)

Writing this book has been a labour of love.

We dedicate the book to

all those who appreciate, admire and enjoy chemistry.

- Authors

Preface

Chemistry got to be recognized as a bonafide subject only towards the end of the 18th century – thanks to Lavoisier. It then made great progress in the traditional branches of chemistry such as organic, inorganic and analytical chemistry. Physical chemistry got duly absorbed as part of the main stream in the early part of the 20th century. 1920s and 30s saw a major change in the nature of chemistry because of the impact of structure and bonding. The chemical bond became a center piece of discussion in chemistry. Many new physical techniques became available for the study of structure. Structure, dynamics and synthesis were considered to be the three main components of chemistry in the 1960-70 period, and advances in chemistry pertained to a great extent to structure and to the discovery of new reactions as well as their mechanisms. Since the early 1970s, a significant change has occurred wherein biology and advanced materials have become major components of chemistry. Today, chemistry has gone beyond the molecular frontier and areas such as self-organization and assembly, complex systems, atmosphere, synthetic biology, and high-level computation have become areas of serious exploration. It was our desire to pay tribute to the great pioneers of chemistry by putting together a book which gives adequate coverage of the times and lives of these chemists besides their contributions.

In this work, we have written about some of the great chemical pioneers whose ideas and contributions have helped to create chemistry as we know it. We start with Lavoisier (Father of chemistry) and end with Sanger. After Lavoisier in the 18th century, we had Dalton and Faraday in the 19th century. Faraday is considered by many to be the greatest scientist of all time. In the early part of the 20th century, chemists created waves with important discoveries related to chemical bonding, molecular structure, reactivity and dynamics, besides synthesis. We have written extensively about chemists in this golden era. In the early part of the 20th century, Mendeleev proposed the periodic table. In organic chemistry, we had Willstätter, Robinson and Woodward who are considered to be the trinity in organic chemistry. Two of the great 20th century chemists who originated many new ideas are G. N. Lewis and Linus Pauling. The 21 chemists we have written about belong to different nationalities: Britain-6, France-1,

Germany-5, Netherlands-1, Russia-1, Sweden-2, Switzerland-1 and United States-4.

As we went through the wonderful journey tracing the growth of chemistry and the lives of the fine people who contributed to it, we have noted the unique attributes, personal idiosyncrasies and philosophical attitudes of these creators. One cannot help noticing the romantic relationship between chemistry and Lavoisier, the devotional approach of Faraday, a great teacher's qualities in Ostwald, an imperious attitude in Arrhenius, an architect's zeal in Lewis, the crusading spirit of a conqueror in Pauling and so on. The romantic involvement of a poet one sees in Lavoisier seems to slowly give way to an accomplishment-oriented attitude of craftsmen and artists as time has gone on. It is noteworthy that most of the pioneers were born in ordinary (even poor) families and became great through their zeal and hard work. Many of them had to overcome serious obstacles to reach the high level of attainment. They had social commitment as well.

It is possible that we have omitted a few pioneers who in the judgment of others should have been included in this book. We would like to be excused for such omission. We ourselves can think of a few chemists who could have been included but we decided to limit the number to 21. We do hope that the readers will pardon us for possible omissions and errors in judgment, and read the book as a recollection of the glorious past of chemistry and an expression of gratitude to the great pioneers. In order to make the book interesting and "real", we have cited extensively from various sources. We have given due credit to the original sources and we earnestly request to be forgiven in case of any mistakes or omissions in citing the literature.

We sincerely thank the invaluable contribution of Jatinder Kaur in formatting and in preparing the print-ready manuscript. Thanks are also due to Sanjay S. R. Rao for his assistance.

Bangalore (India)
2015

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Indumati Rao

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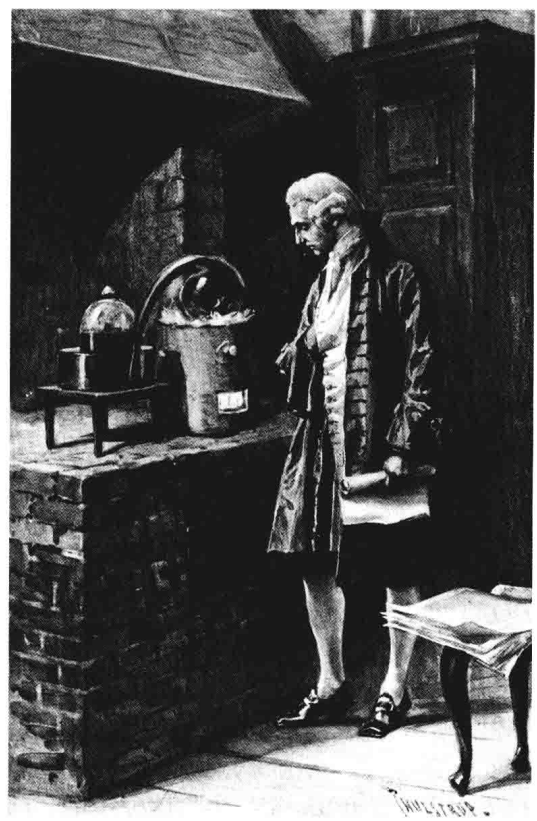
1. ANTOINE LAVOISIER (1743–1794)

Father of chemistry

The year 1994 marked the 200th death anniversary of Lavoisier. In the preface to the article *The life and legacy of Antoine Laurent Lavoisier* to commemorate the life and legacy of the father of modern chemistry, Peter Childs wrote "*It is more than 200 years this year the greatest chemist of all time - Antoine-Laurent Lavoisier – became a victim of the irrational mob fury of the French Revolution. Lavoisier died at the age of 51 at the height of his creative powers and after establishing modern chemistry on a firm footing. Who knows what more he might have achieved had he lived? Every modern chemist, indeed every chemist for the last 200 years, lives in the shadow and on the legacy of Lavoisier. It is instructive 200 years later to look back at Lavoisier's life and achievements, to the very birth of modern chemistry. Before he died the phlogiston theory was dead....and the oxygen theory of combustion and respiration was firmly established. Lavoisier laid his personal claim to be the author of the chemical revolution in 1792*" (From Childs [1]).



(From *Understanding Chemistry*)

Chemistry was not a well-defined subject in the early 18th century and Lavoisier propelled chemistry and established it as an experimental science.

"The coping-stones of eighteenth century chemistry, which are at the same time the foundation-stones of the modern science, were laid by Antoine Laurent Lavoisier (1743-1794)....." (From Holmyard [2]).

Lavoisier is believed to have said *"I am young and avid for glory"* (From the Website scienceworld.wolfram.com [3]) when he was a young student. He lived up to this self-belief in every role he played during his lifetime. Lavoisier was a polymath in the renaissance mould of Leonardo da Vinci.

Early years

Antoine Laurent Lavoisier was born on August 26, 1743 in an affluent family. His father, Jean Antoine Lavoisier, was a wealthy and successful lawyer and was close to the powerful aristocracy as he was also an *avocatau parlement* (parliamentary counsel). His mother Emille Punctis was the daughter of a rich attorney. Lavoisier lost his mother when he was five years old and went to live with his maternal grandmother and aunt. His aunt devoted her life to him and upon her death, left her considerable wealth to him. The double inheritance made him independently wealthy and came as a boon when the time came to choose a career. He could choose any career that he fancied without worrying about the payslip. Lavoisier's father was particular that young Lavoisier should get the best possible education that combined the rigors of science with liberal education of humanities that inculcated social awareness. He enrolled young Lavoisier in College des Quatre Nations when he was 11 years old as a day scholar, to receive a holistic and liberal education there. Later at the College Mazarin under a number of inspiring teachers Lavoisier studied (in addition to mathematics, astronomy) botany (de Jussieu), geology (Guettard), chemistry (Rouelle), languages and literature. He not only gained theoretical knowledge in science subjects by attending their lectures but also gained practical skills by working in laboratories and doing field work with Guettard. This unique blend of proficiency in science and classical and liberal arts contributed to Lavoisier's breadth of interest in science and commitment to social justice that he displayed throughout his professional life. He also graduated in law in 1763 and obtained a license to practice

law in 1764. He was expected to follow the family tradition and take up law as his profession, but his path to glory was elsewhere.

Lavoisier grew up during the period of French enlightenment and was inspired by its ideals. His was a rare intellect that could combine the demands of public office with the pursuit of science. He was attracted to the excitement of science as well as to the need to work for social causes. He studied geology for four years from 1763 to1767 under Guettard who was a member of the Royal Academy of Sciences. During this period, he toured the Alsace-Lorraine region and conducted experiments on the geology of the rocks of the region. Young Lavoisier was fascinated by everything he saw around him and took copious notes on the vegetation, nature of soils, daily temperatures and mines. On the basis of this study, he presented a paper on the physical and chemical properties of hydrated calcium sulfate (gypsum) to the French Academy of Sciences in 1764. His interest in the problems facing the general public in Paris at that time led him to study the problem of inadequate street lighting which led to social problems. In 1766, he submitted an essay about these problems and possible solutions to the competition organized by the French Academy of Sciences. It is said that he studied various types of lamps and compared the different kinds of oils and wicks used by them. He drew detailed diagrams to show the amount of light generated and the area lit up by different lamps. He also presented in his essay the cost of maintenance. Though he did not win a prize, the judges were so impressed by the thoroughness of the presentation and the original solutions offered by Lavoisier that they gave him a special gold medal which was presented by King Louis XV. The Academy took the usual step of publishing the essay. In recognition of these contributions, he was elected to the French Academy of Sciences in 1768 when he was only 25 years old.

Around this time, he turned his attention to chemistry as he was fascinated by the well known French chemist Pierre-Joseph Macquer's *Dictionnaire de chymie* published in 1766. However, it was the prominent French scholar, Etienne Condillac, who inspired his life-long passion and devotion to chemistry.

When he became 26 years old, it became imperative for Lavoisier to choose a career. Rather than take up a job with the French Academy, Lavoisier bought stock in *Ferme Generale*, a private company that collected agricultural taxes in lieu of the advance (based on the estimated profit made by the farming community) made to the king and he became a tax collector. While this choice of career afforded him the time and finances to pursue chemistry, it proved to be a fatal choice 26 years later!

In 1775, Lavoisier was appointed to Gun Powder Commission as one of the four commissioners. Their brief was to devise methods of improving the quality of the gun powder and also to improve its supply to the government. This appointment entitled him to a large house at the Royal Arsenal where he lived from 1775 to 1792. He spent his own money to convert part of the house to one of the best equipped laboratories in France where he pursued his scientific work without any external distractions. In a short time, it became the meeting place for distinguished scientists and free thinkers from all over Europe.

Lavoisier and du Pont: Eleuthère Irénée du Pont (1771-1834), founder of the du Pont Company, was the son of Pierre du Pont a reform minded government official. When Lavoisier took up the task of reforming the Royal Gunpowder and Saltpeter Administration, he hired Pierre's son Eleuthère Irénée du Pont to work in the gunpowder factory at Essonne. Years later during the French Revolution, the du Pont family were forced to emigrate to America. They settled down in Wilmington, Delaware, where Irénée du Pont set up the original gunpowder factory which later became one of the biggest chemical industrial houses.

Marriage: In 1771, Lavoisier married Marie-Anne Pierrette Paulze, his colleague's daughter, 14 years younger to him. Though she had no exposure to the world of science, young Marie-Anne plunged into Lavoisier's world of chemistry. As Lavoisier did not know English, she learnt English so that she could translate the research papers published in England by contemporary scientists (especially those of Priestley and Cavendish) and Richard Kirwan's *Essay on Phlogiston.* She learnt painting and the art

of engraving so that she could illustrate Lavoisier's work and make engravings of the instruments used by Lavoisier. She was always present in the laboratory when Lavoisier was conducting experiments and also at the meetings of scientists who visited the laboratory. In a short time she became Lavoisier's invaluable collaborator. Her drawings and illustrations added immense value to Lavoisier's writings.

(From "Antoine Lavoisier", *Wikipedia*)

"Lavoisier changed the whole structure and outlook of chemistry, the science which more than any other touches our daily lives, and which affects them in almost every phase" (From McKie [4]).

Lavoisier's Chemistry

Lavoisier considered Nature as *"a vast chemical laboratory in which all kinds of compositions and decompositions are formed"* (From Lavoisier [5]). His approach to chemistry is best described in his own words: *"We must trust to nothing but facts: These are presented to us by Nature, and cannot deceive. We ought, in every instance, to submit our reasoning to the test of experiment, and never to search for truth but by the natural road of experiment and observation"* (From Lavoisier [5]).

"*Thoroughly convinced of these truths, I have imposed upon myself, as a law, never to advance but from what is known to what is unknown; never to form any conclusion which is not an immediate consequence necessarily flowing from observation and experiment; and always to arrange the facts, and the conclusions which are drawn from them, in such an order as shall render it most easy for beginners in the study of chemistry thoroughly to understand them*" (From Lavoisier [5]).

When Lavoisier began his foray into chemistry, the subject was little understood and was so underdeveloped that it was not even considered as a serious scientific discipline (unlike physics and mathematics which were well defined disciplines). Chemistry at that time was highly descriptive and qualitative. Lavoisier changed this and established that chemistry was essentially an experimental science.

He felt that time had come to *"recall chemistry to a more rigorous method of reasoning; to strip away the facts with which this science is enriched every day from that which reasoning and prejudices add thereto; to distinguish fact and observation from that which is systematic and hypothetical; finally, to mark the limit, so to speak, to which chemical knowledge has arrived, in order that those who follow us may set out with confidence from this point to advance the science"* (From Lavoisier [6]).

Conservation of Mass: Lavoisier was convinced that the total weight of the reactants and products would be conserved in any chemical reaction. He categorically stated that *"We may lay it down as an incontestible axiom, that, in all the operations of art and nature, nothing is created; an equal quantity of matter exists both before and after the experiment; the quality and quantity of the elements remain precisely the same; and nothing takes place beyond changes and modifications in the combination of these elements. Upon this principle the whole art of performing chemical experiments depends: We must always suppose an exact equality between the elements of the body examined and those of the products of its analysis"* (From Lavoisier [5]). ... *"As the usefulness and accuracy of chemistry depends entirely upon the determination of the weights of the ingredients and products ....., too much precision cannot be employed in this part of the subject, and for this purpose, we must be provided with good instruments"* (From Lavoisier [5]). This underscored the need for accurate measurement of the reactants before the chemical reaction took place and the resultant products. As the balances available at that time could not measure accurately, Lavoisier collaborated with Laplace and developed a balance.